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Mechanical Properties of Block Masonry Units Manufactured From Different Kinds of Recycled Materials

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Abstract

This experimental investigation is carried out to study and determine the difference in strength of block masonry units manufactured from six different kinds of recycled materials. Large numbers of solid and hollow concrete block units were prepared with some changes in the materials used to manufacturing each type. The changes included the use of chopped worn-out tires, broken pottery, broken pantiles, broken bathroom tiles and melted down glass pieces instead of coarse aggregates. Different percentages of steel wastes were also added in three different mixes having natural aggregates. The characteristic studied were the stress-strain curves, the modulus of elasticity and the compressive strength. The above characteristics were compared with others obtained from testing concrete units manufactured from natural aggregates. The possibility of using each type of the units in the construction of bearing and non-bearing walls is given.

Keywords: Recycled aggregates, masonry units, mechanical Properties, Hollow blocks, solid blocks.

1. Introduction

A number of researchers tried to make some modifications on the components of concrete mixes using new materials instead of regularly used fine or coarse aggregates (Al-Hadithi et al. 1999; Yasin 2012). These modifications aim to produce concrete mixes made from new resources, at the same time to give an acceptable strength, and from the economical point of view, it reduces the coasts.

This research aims to manufacture solid and hollow concrete full and half-block units from recycled materials instead of natural coarse aggregates using standard molds having 390 × 190 × 190 mm and 390 × 190 × 190 mm in dimensions. The hollow block units were consisted of two and one R-type core (with recessed end) for full and half block units respectively. This size of the units was chosen because it could be used in both load-bearing and ordinary partition walls as well; in this case, less thickness is preferred. In the recent technology of building construction, grout material could be used to fill the hollow-blocks holes or voids; it added strength to the wall. It could be reinforced also by steel in constructing reinforced concrete masonry columns and walls. The units size, shape and detailing were chosen from standard specifications of precast concrete masonry units (Abrams 1994; Roberts 2001).

2. Materials

Nine types of different concrete batches were adopted to construct all the specimens with some changes in the coarse aggregates used in manufacturing each type. The changes were the use of five kinds of recycled coarse aggregates. The recycled material used in manufacturing those types were: chopped worn-out tires chopped from old and disposable tires, crushed pieces of rejected broken pottery, broken roof tile pantiles, broken bathroom tiles and glass pieces from melted down glass bottles.

The coarse aggregate was divided into two different sizes by using three standard sieves having 12.5 mm, 9.5 mm and 4.75 mm apertures (ASTM C 33-86). Figure 1 shows two divided sizes of the chopped worn-out tires, it shows two aggregate sizes retained on 9.5 mm and 4.75 mm aperture sieves. Figure 2 shows the crushing of broken pantile pieces to proper sizes. Figure 3 shows two sizes of crushed pantiles used as coarse aggregates. It shows two aggregate sizes retained on 9.5 mm and 4.75 mm aperture sieves.

Figure 4 shows the crushed broken bathroom tiles ready for the sieve analysis.

Figure 5 shows three old glass bottles and two small glass balls ready to be melted in the furnace. Figure 6 shows the melted down pieces of glass after crushing it to small pieces and ready for the sieve analysis.

Three of the remaining four batches were mixed with steel scobs brought from a metal workshop; those were manufactured from three scobs percentages added to each concrete mix. Figure 7 shows the steel scobs used in three different mixes with three different percentages. The steel scobs percentages were 6%, 12% and 24% of the cement weight. The last batch was mixed from natural fine and coarse aggregates.

3. Specimens Construction

For all specimens, one proposed mix with 1 : 2 : 4 (cement : sand : coarse aggregate) proportions batched by volume was used. Average water content was adjusted to provide concrete of medium slump. The grading requirements for fine and coarse aggregates were in accordance with ASTM C 33 – 1986 (Annual Book of ASTM Standards 1986). With each batch of concrete, three 100 × 100 × 100 mm cubes were casted then cured in water and tested in compression after 28 days. One or more 100 × 200 mm cylinders from each batch were also casted to determine the modulus of elasticity. Ordinary Portland cement was used in all mixes. All the recycled mixes and the ordinary mix were placed in about 50 mm layers inside steel molds specially prepared for this study. Each concrete layer was hand compacted using the same steel rode commonly used for compacting concrete cubes. After twenty-four hours, the casted block units were removed from the molds and cured in a water tank for fourteen days then removed and left for further fourteen days before testing.

4. Strain Measurements

To study the relationships between stresses and strains for the hollow units demec points with gauge length of 50 mm were glued and centered about the midheight of the specimens in identical positions both sides of one out of three specimens of each type. The same method was arranged on the cylinders in order to determine the modulus of elasticity. The cylinders were lifted twenty-four hours to ensure that the glue had fully dried. The positions where the gauges were glued are shown in fig. 8a and fig. 8b.

5. Testing Procedure

The densities of hardened concrete manufactured from different recycled aggregates were carried out by water displacement method in accordance with clause 7 of BS 188: Part 113: 1983 (BS188: 1983).

All the specimen were tested under axial compression using 1.3 MN capacity hydraulic testing machine at a loading rate of 10 N/mm^2 per minute in accordance with BS 6073: Part 1: 1981 (BS 6073: 1981). For units with strain gauges, initial readings were taken at zero loads. The load then applied with the above required loading rate until a stress of 0.5 N/mm^2 was reached, this is when the first set of readings were taken. The load on the specimen was then increased in small increments until failure.

For determining the compressive strength of the block units, the average value of three tests of each type of the block units was considered. The stress-strain relationships for the hollow full-block specimens are shown in fig. 9a,b and fig. 10a,b. Figure 11a,b shows the stress-strain relationship for the hollow half-block specimens.

The compressive strength of the recycled materials used in this study was tested in accordance with BS 1881: Part 116: 1983 (BS 1881: 1983) at a rate of 0.2 – 0.4 N/mm^2 per second.

The modulus of elasticity tests for the different materials used in this study was conducted in accordance to ASTM C 469-83 (Annual Book of ASTM Standards 1986).

6. Results and Discussion

Tables 1 and 2 give the sieve analysis results for both coarse and fine aggregates. The results given are conforming to the grading requirements for fine and coarse aggregates of the ASTM C 33 (Annual Book of ASTM Standards 1986).

Table 3 gives different values of compressive strengths for the materials used in manufacturing the blocks ranging from 2.5 N/mm^2, for 100 × 100 × 100 mm cubes with chopped worn-out tires coarse aggregate, to 29.8 N/mm2 for cubes with crushed glass coarse aggregate. Table 1 also gives the average compressive strength of solid and hollow block masonry units manufactured from different types of recycled materials. The units manufactured of crushed pottery coarse aggregates possess the highest compressive strength of tested 190 × 190 × 190 mm solid blocks. For the hollow half-blocks, units manufactured from crushed pantile possess the highest compressive strength of 21.8 N/mm^2 while for, hollow full-blocks one can see that units with added steel scobs of 24% posses the highest compressive strength of 18.6 N/mm^2.

Table 4 gives the results of the density of the concrete used in manufacturing all the solid and hollow full and half-blocks. Comparing the densities of concrete samples manufactured from recycled coarse aggregates with the density of concrete sample built from natural aggregates shows that the densities of coarse aggregates built from chopped worn-out tires, crushed pottery, crushed pantile and crushed bathroom tiles are lower by 28.4%, 12.1%, 6.25% and 12.02% respectively from the natural aggregates sample. Table 4 also gives the results of modulus of elasticity for the different materials used in manufacturing the blocks. The table gives different values ranging from 3479 N/mm^2 for the materials used in manufacturing the block units with chopped worn-out tires type of coarse aggregate to 15766 N/mm^2 for the materials used to manufacture the block units having natural crushed stone coarse aggregate with added steel scobs of 24%.

Figure 9a,b and 10a,b shows the stress-strain curves for the hollow full-blocks. Figure 11a,b shows the stress-strain curves for the hollow half-blocks. For most of full and half-hollow blocks, the mode of failure observed was a result of one or more longitudinal cracks near the block corners that started at early or middle stages of the loading process followed by splitting of the cracked block shells. Shear cracks were also noticed at midhight of the web of the full hollow-blocks.

For both full and half hollow-block, the curves of steel scobs show high vertical strains reached before failure. High strains were noticed near failure for the blocks manufactured from chopped worn-out tires.

Figure 12 shows some units manufactured from chopped worn-out tires after testing.

7. Conclusions

Based on the previous test results, the following conclusions can be drawn:

1- Block masonry units manufactured from different recycled materials can be used in different concrete mixes with satisfactory engineering properties.

2- Chopped worn-out tire coarse aggregates can be used in manufacturing blocks for non-bearing walls mostly as partition walls with its remarkable lower densities than blocks manufactured from natural aggregates. Coarse aggregates made from crushed bathroom tiles are accepted for manufacturing block units for constructing non-bearing walls. Crushed pottery and crushed pantiles, which have slightly lower densities than the natural aggregate used for normal blocks could be very good for constructing non-bearing masonry walls.

3- The block units manufactured from crushed glass with densities above the natural aggregate units and block units with added scobs having densities above the natural aggregates units can be used in the construction of load-bearing walls.

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Figure 1. Two sizes of chopped worn-out tires used as coarse aggregates.

Figure 2. Crushing the broken pantile pieces to proper sizes.

Figure 3. Two sizes of the crushed pantiles used as coarse aggregate.

Figure 4. Crushing the broken bathroom tiles to proper sizes.

Figure 5. Three glass bottles and two small glass balls ready to be melted in the furnace.

Figure 6. The melted down glass aggregates.

Figure 7. Steel scobes used in three different mixes with three different percentages.

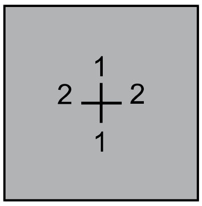


Figure 8a.The positions of strain measurements on one of the opposite faces of half-block specimens.

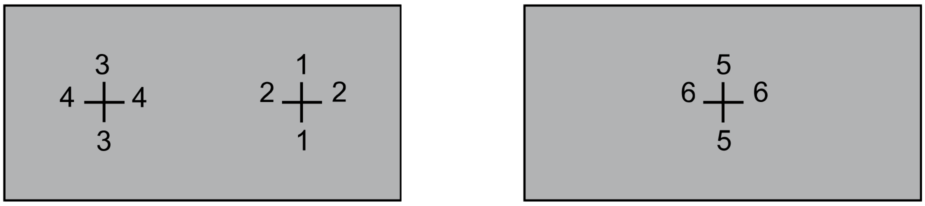
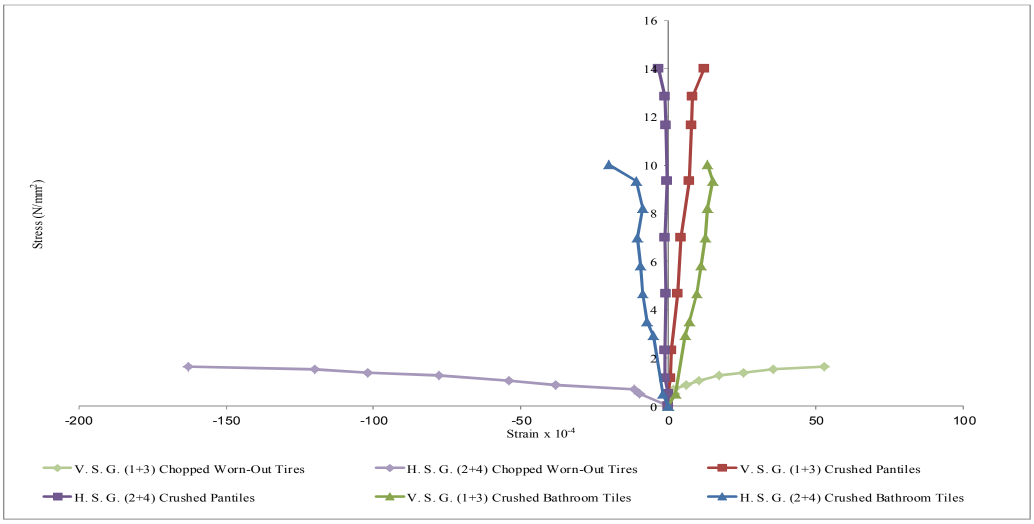


Figure 8b. The positions of strain measurements on one of the opposite faces of full-block specimen



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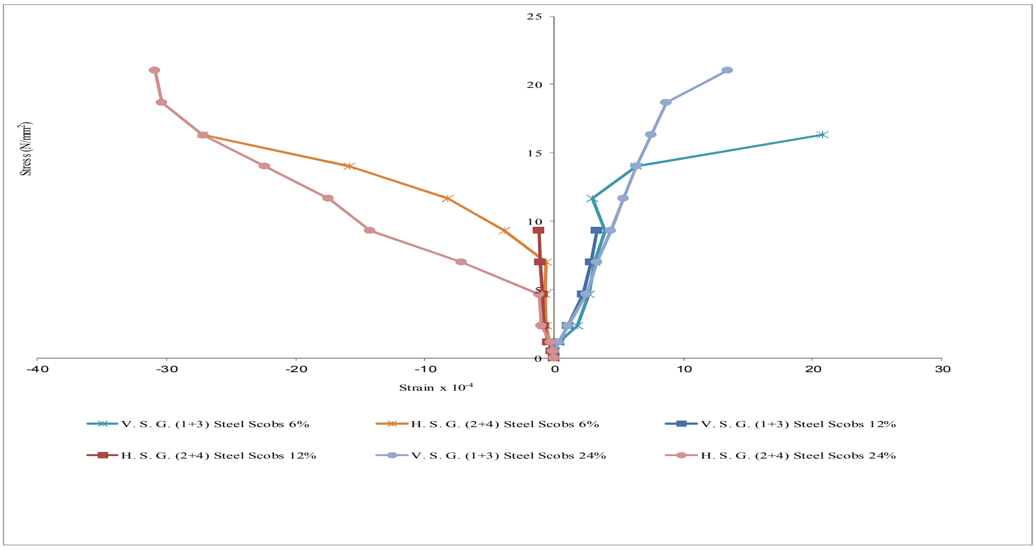
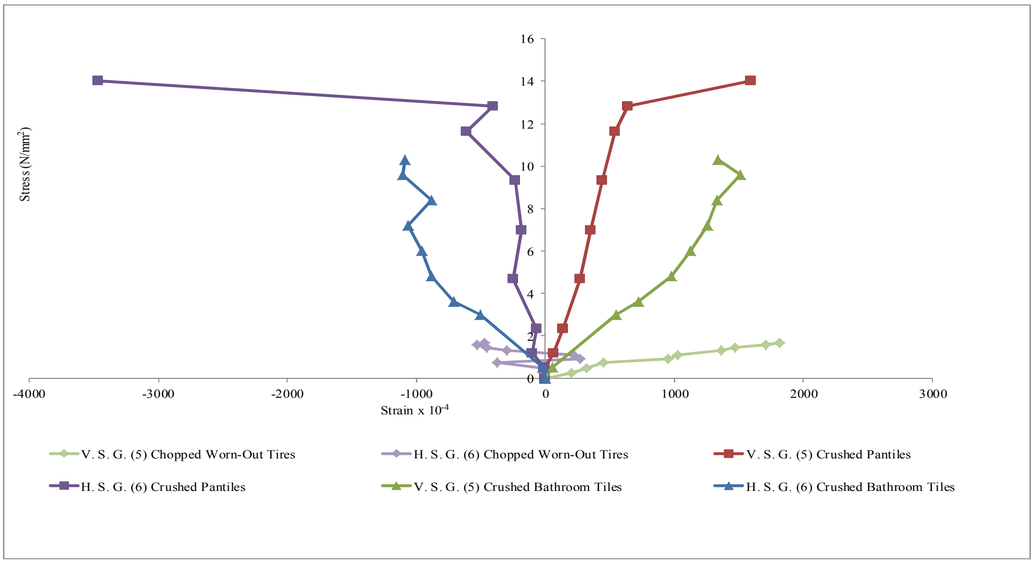


(b

Figure 9a,b. Stress-strain curves for hollow full-blocks manufactured from different coarse aggregate materials (for strains measured at positions (average of 1+3)&(average of 2+4)).



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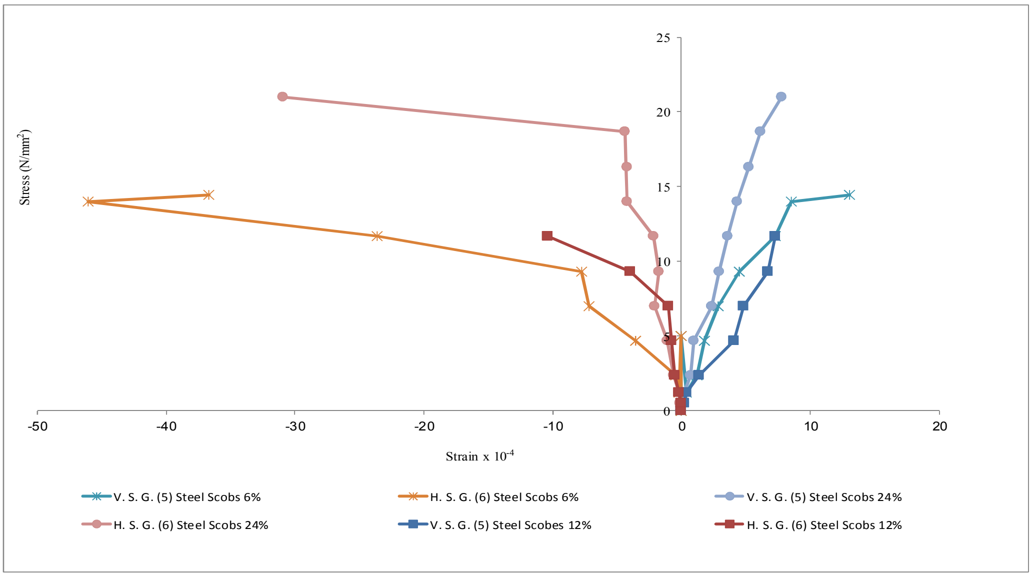
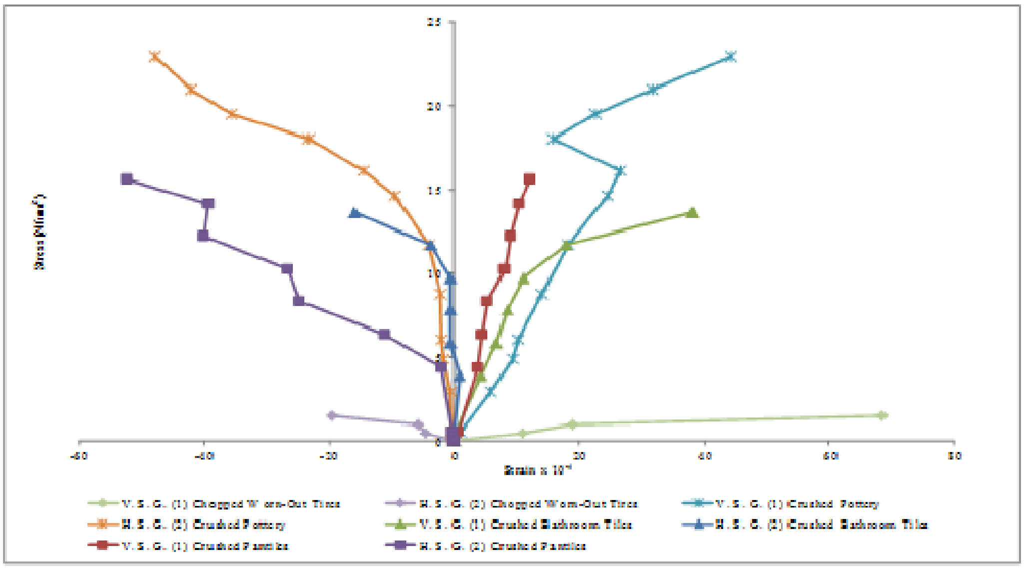


(b

Figure 10a,b. Stress-strain curves for hollow full-blocks manufactured from different coarse aggregate materials (for strains measured at positions 5&6).



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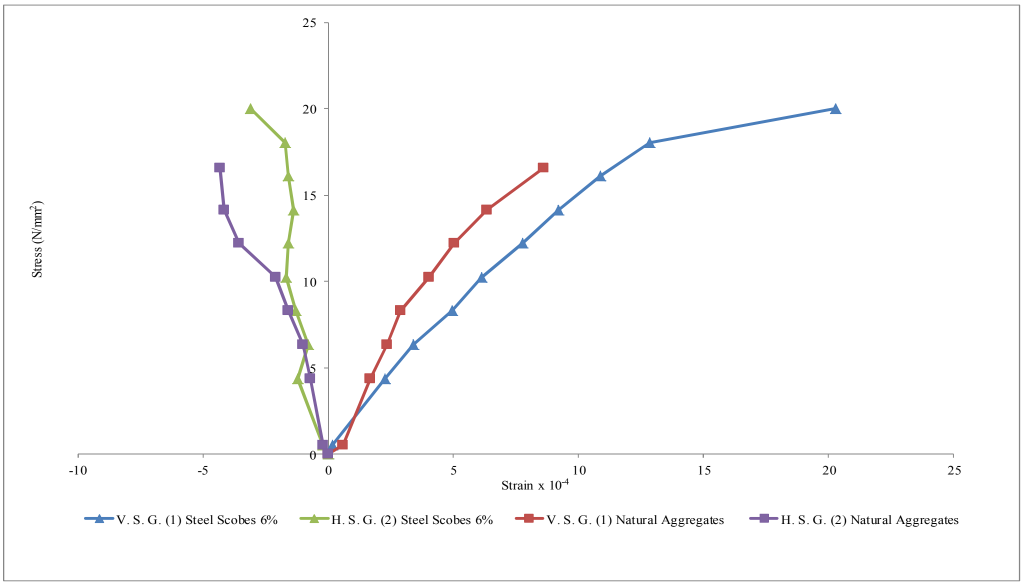

b)

Figure 11a,b. Stress-strain curves for hollow materials (for strains measured at positions 1&2).half-blocks manufactured from different coarse aggregate

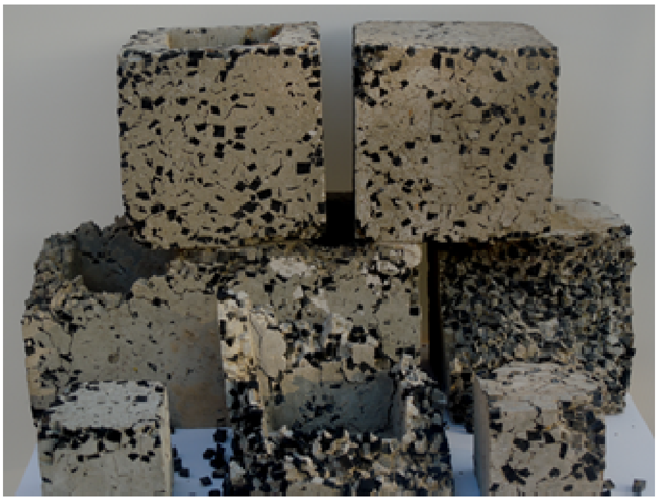

Figure 12. Some units manufactured from chopped worn-out tires after testing.

Table 1. Sieve analysis of coarse aggregate

Aperture	Passing through sieve (%)	
	Test results	ASTM C 33
19 mm	100	100
12.5 mm	100	90-100
9.5 mm	40	40-70
4.75 mm	0	0-15
2.36 mm	0	0-5

2. Sieve analysis of fine aggregate

Aperture	Passing through sieve (%)	
	Test results	ASTM C 33
9.5 mm	100	100
4.75 mm	100	95-100
2.36 mm	91	80-100
1.18 mm	64	50-85
600 µm	29	25-60
300 µm	12	10-30
150 µm	2	2-10

Table 3 The compressive strength of solid and hollow half and full-block units manufactured from different types of recycled coarse aggregates.

Type of the Coarse Aggregate	Compressive Strength (N/mm^2) *				
	Cubes 100×100×100 (mm)	Solid Half-Block 190×190×190 (mm)	Solid Full-Block 390×190×190 (mm)	Hollow Half-Block 190×190×190 (mm)	Hollow Full-Block 390×190×190 (mm)
Chopped Worn-out tires	2.5	2.1	3.2	2.0 (1.1)	1.7 (1.0)
Crushed Pottery	23.1	22.7	> 17.5**	19.1 (10.7)	16.2 (9.4)
Crushed Pantile	21	19.5	14.4	18.7 (10.5)	14.4 (8.3)
Crushed Bathroom tiles	19.8	10.9	10.1	14.1 (7.9)	10.3 (6.0)
Crushed Glass	29.8	Not tested	Not tested	20.4 (11.5)	Not tested
Steel Scobs (24%)	22.5	16.1 19.3	> 17.5**	19.8 (11.1)	18.6 (10.8)
Steel Scobs (12%)	23.0	21.3	> 17.5**	20.1 (11.3)	17.9 (10.4)
Steel Scobs (6%)	25.9	19.1	> 17.5**	20.6 (11.6)	17.7 (10.2)
Natural Aggregate	22.5	18.8	13.5	16.13 (9.1)	14.9 (8.6)

Values in brackets are for stresses calculated taking the block gross area.

* Areas used in the calculation of the compressive strength:

Net area = 20500 mm^2 (half-block), 42900 mm^2 (full-block).

Gross area = 36100 mm^2 (half-block), 74100 mm^2 (full-block).

** The load reached the ultimate machine capacity of 1300 kN with no sign of failure.

Block percentage solid (for hollow blocks) = 62%.

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Table 4. The density and the modulus of elasticity of recycled concrete materials used in manufacturing all the blocks.

Type of the Coarse Aggregate	Density (Kg/m^3)	Modulus of Elasticity (N/mm^2)
Chopped worn-out tires	1490	3479
Crushed Pottery	1827	9550
Crushed Pantiles	1950	6639
Crushed Bathroom tiles	1830	9460
Crushed Glass	2310	12366
Steel Scobs (24%)	2330	15760
Steel Scobs (12%)	2290	Not Tested
Steel Scobs (6%)	2111	14947
Natural Aggregate	2080	14808